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INVESTIGATING THE RELATIONSHIP BETWEEN OZONE AND WATER-ICE CLOUDS IN THE MARTIAN ATMOSPHERE

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Ozone on Mars

- Trace gas in the martian atmosphere $<0.01\%$ ¹
- Breaks down in ultraviolet (UV) light; 220-280nm^{1,2}
- Used to track general circulation of the atmosphere and other trace gases²
- Is anticorrelated with water vapour (can be used as a proxy)^{2,3,4}
- Varies diurnally and seasonally⁴

Composition of martian atmosphere

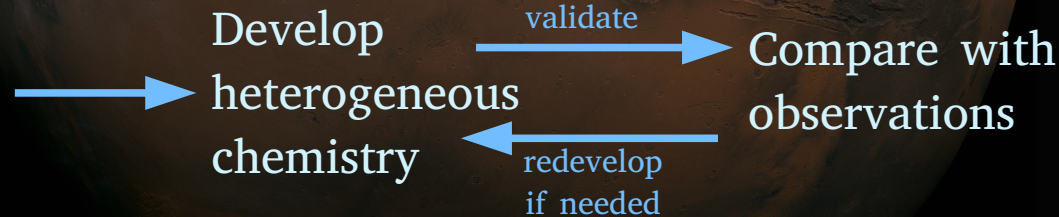
Gas	Volume / %
Carbon dioxide	95.32
Nitrogen	2.7
Argon	1.6
Oxygen	0.13
Carbon monoxide	0.08
Water	Trace
Ozone	Trace

Aim: Improve the current understanding of the chemical processes in the martian atmosphere by investigating the interaction between ozone and water-ice and heterogeneous chemistry

Method: Use the 1-dimensional Laboratoire de Météorologie Dynamique (1-D LMD)^{1,2} model to simulate a column of the atmosphere

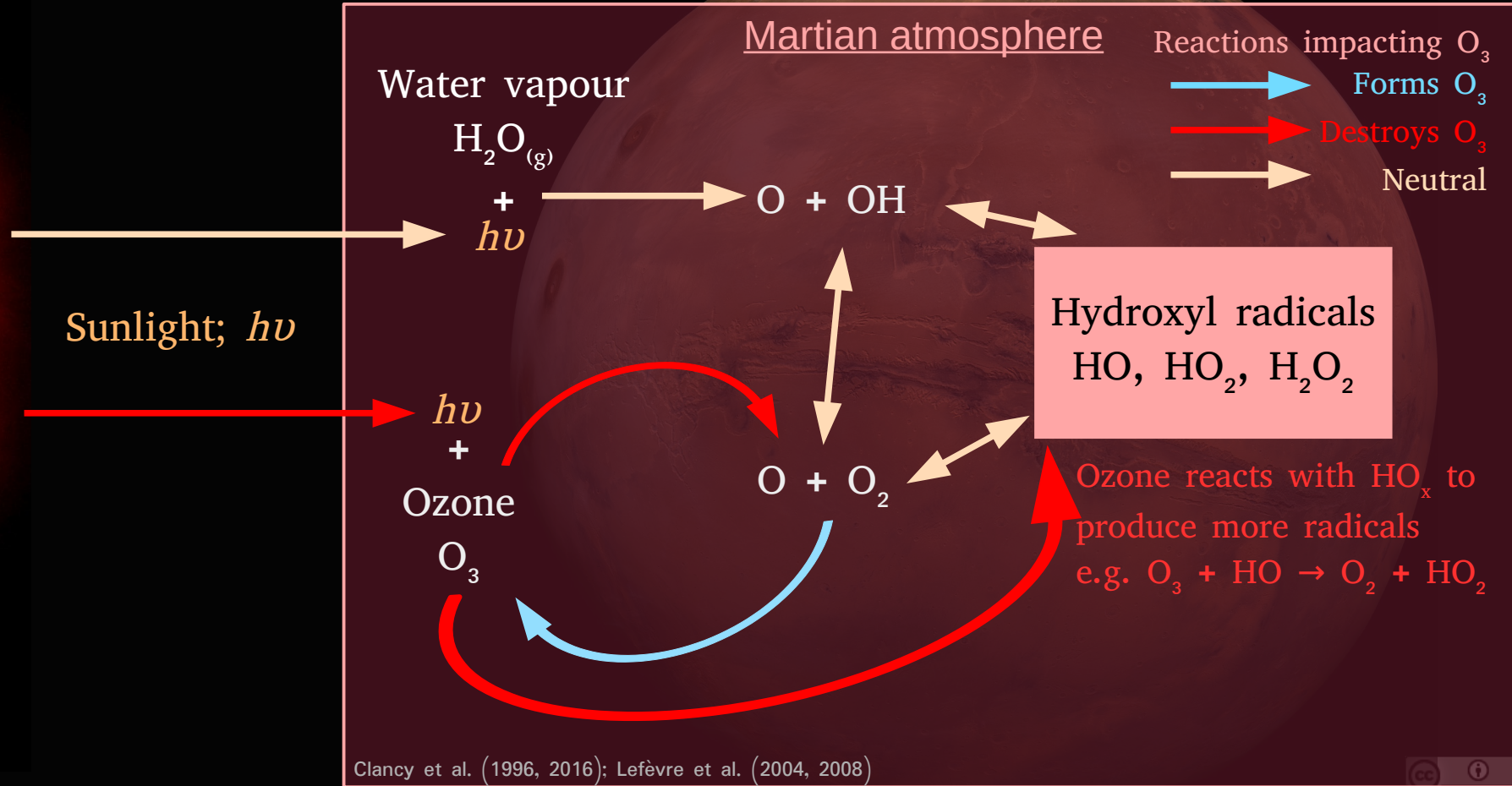
Test 1-D model:

- Current hetero/homogeneous chemistry
- Equatorial and polar latitudes

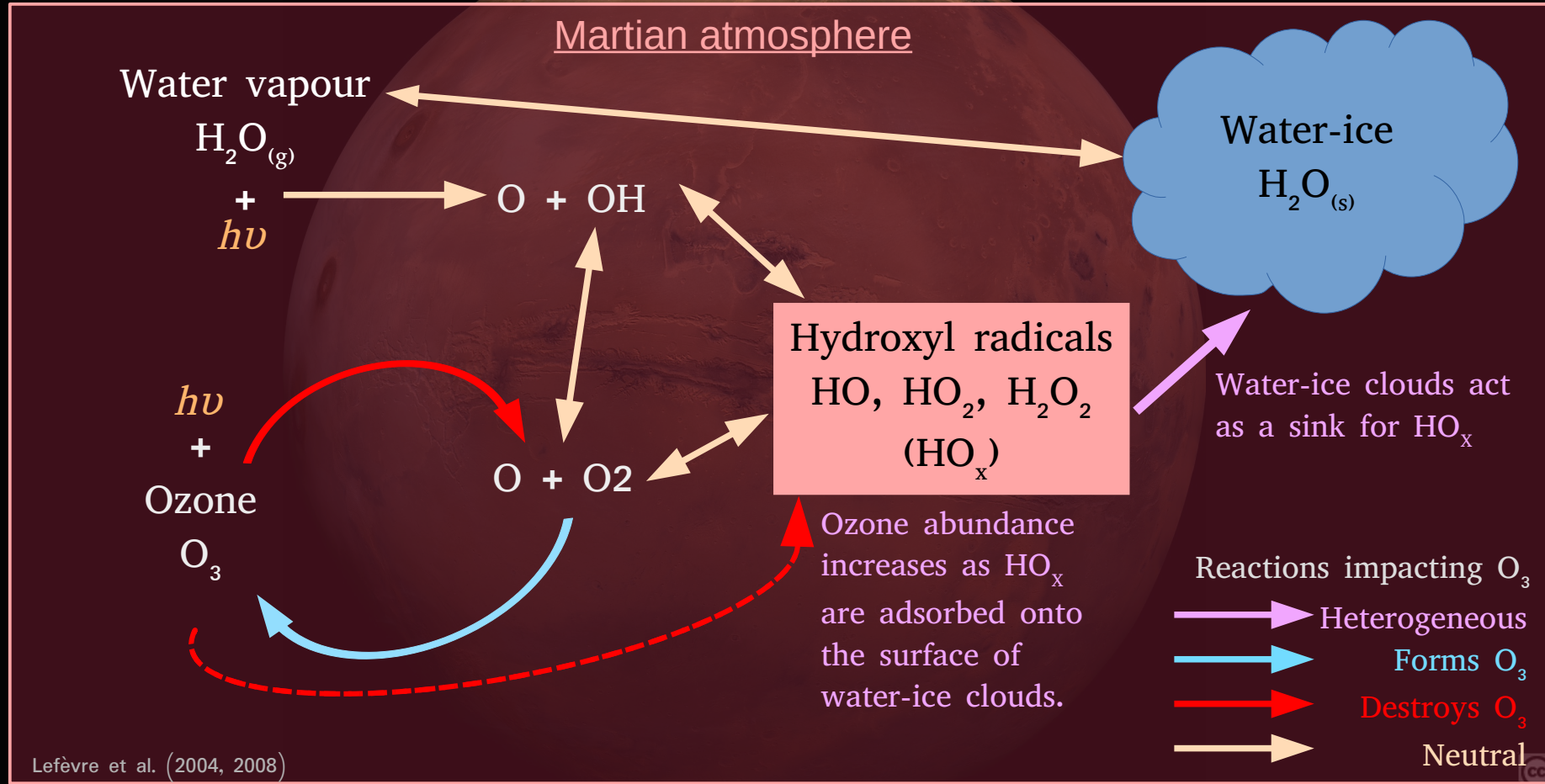


Model: The 1-D model is a physical submodel from the LMD global climate model (GCM) suited for testing chemical processes as it is not as computationally expensive as a full GCM.

Martian atmospheric chemistry



Heterogeneous chemistry



Current models

The heterogeneous GCM run over-predicts ozone abundance during aphelion, while the homogeneous run under-predicts during the start of aphelion

Neither model captures the increase in ozone just before L_s 50° well

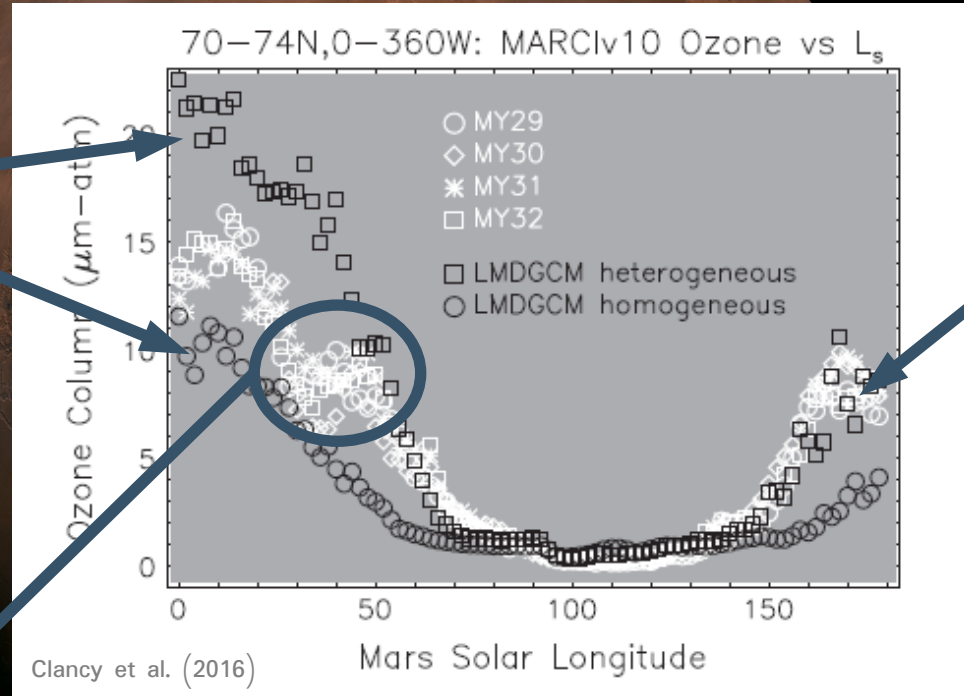
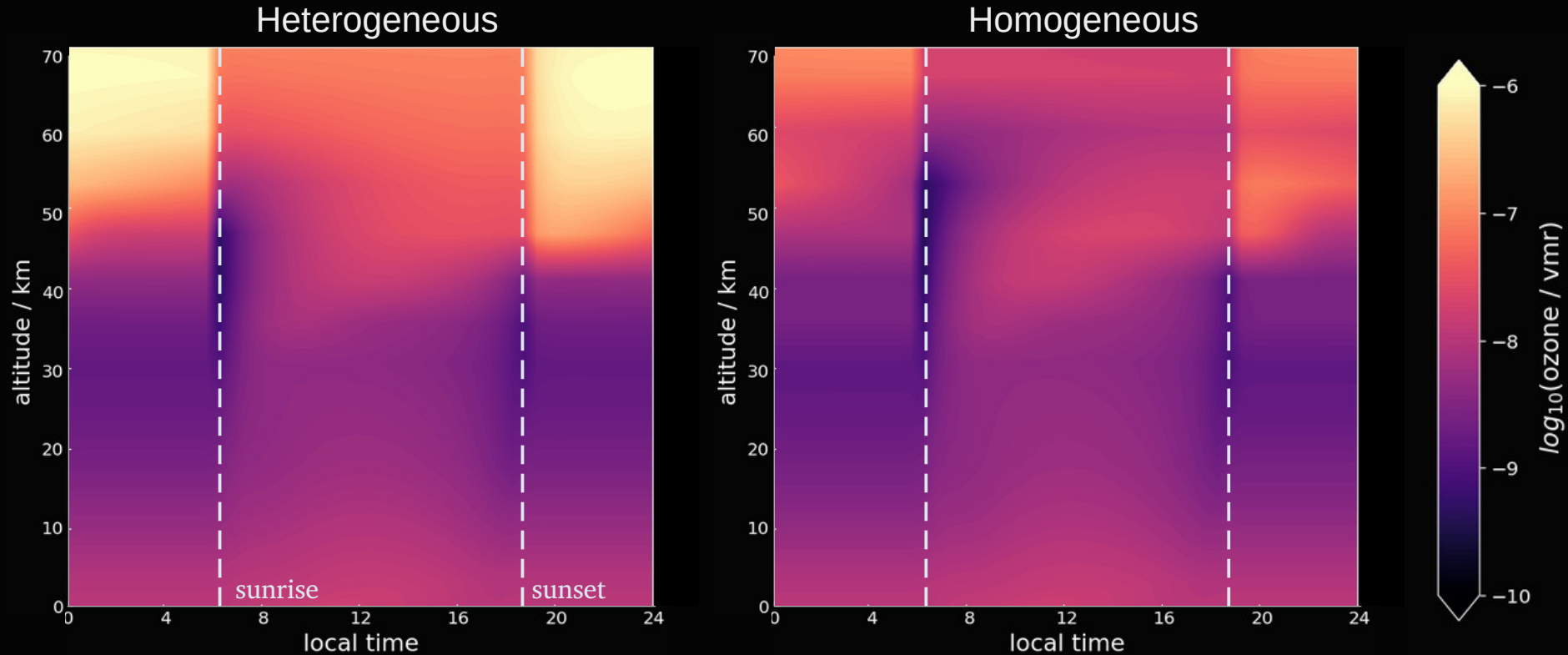


Fig. 11. The spring to fall ($L_s = 0-180^\circ$) evolution of northern high latitude O_3 (70–74N) is presented for zonally averaged, $L_s = 2^\circ$ binned MARCI measurements (MY29–32, white symbols) and LMD GCM simulations for homogeneous (black circles) and heterogeneous (black squares) O_3 photochemistry. Neither model captures the observed spring behavior well, including an $L_s = 40-50^\circ$ secondary maximum (which exhibits the largest interannual variations among the observed MY). The heterogeneous model provides significantly improved comparison over the homogeneous model to the observed early fall ($L_s = 150-180^\circ$) O_3 increases.

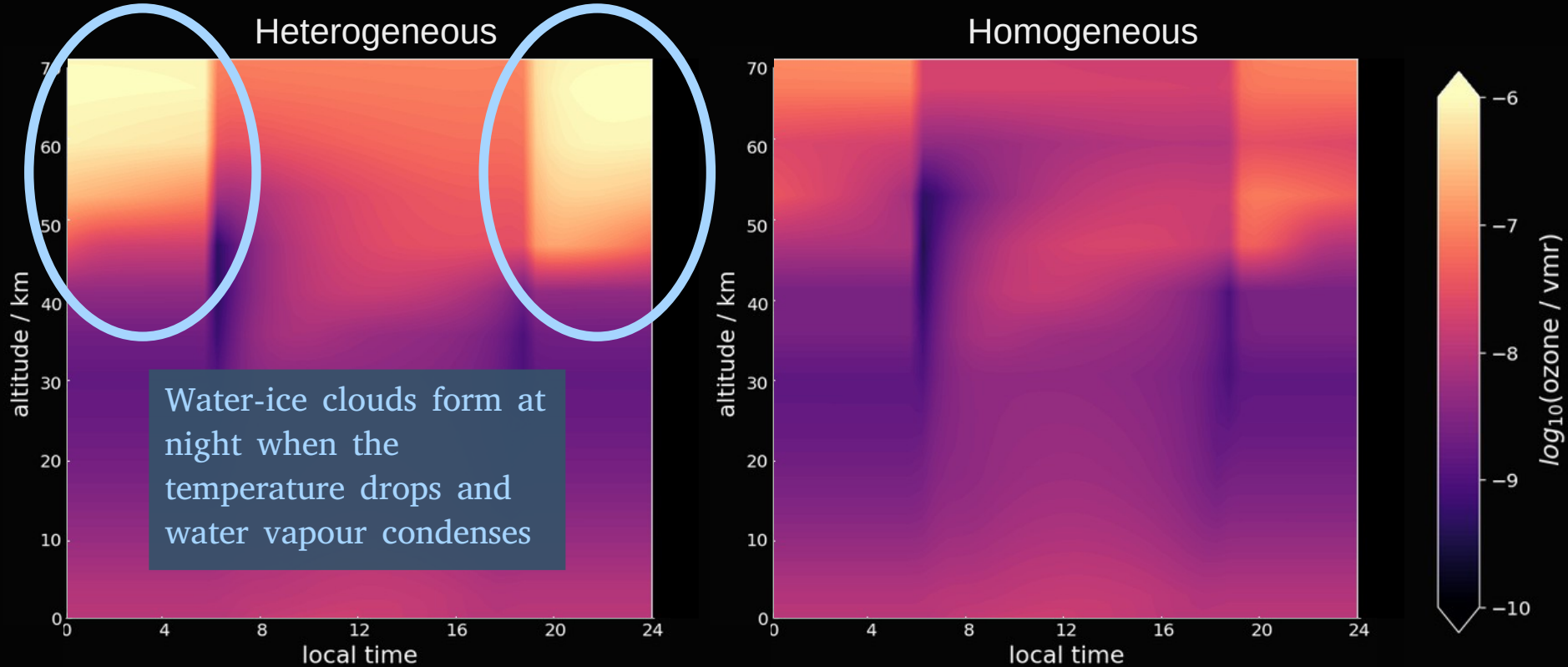
The heterogeneous model captures the increase in ozone from L_s 150° onwards

1-Dimensional modelling (diurnal)



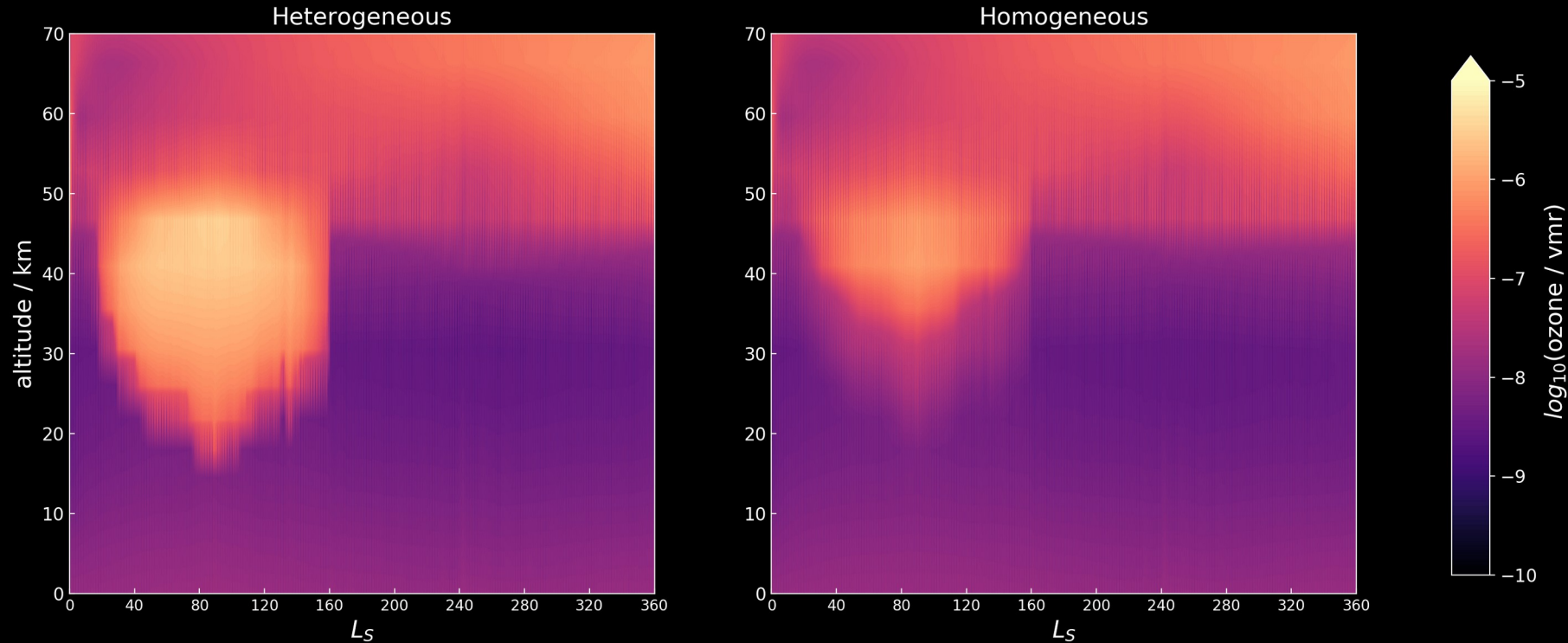
Simulated diurnal vertical profile of ozone with heterogeneous chemistry (left), and homogeneous chemistry (right) over one sol, at latitude 0° and $L_s 0^\circ$.

1-Dimensional modelling (diurnal)



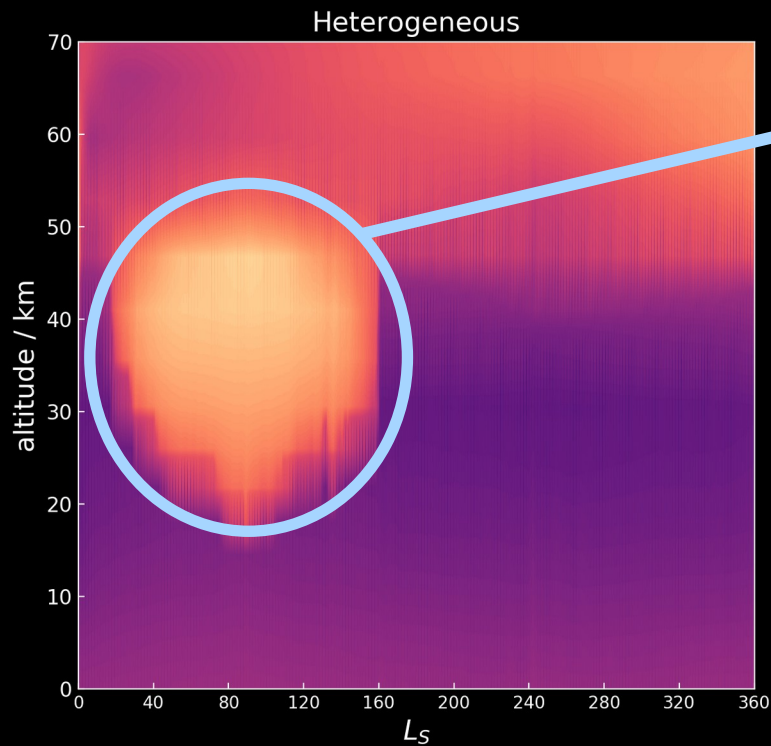
Simulated diurnal vertical profile of ozone with heterogeneous chemistry (left), and homogeneous chemistry (right) over one sol, at latitude 0° and $L_s 0^\circ$.

1-Dimensional modelling (annual)

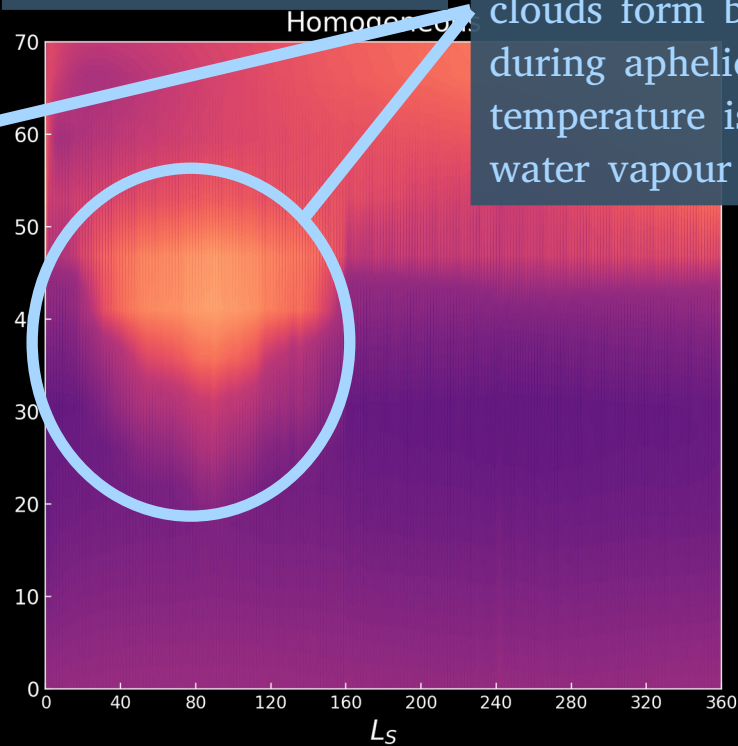


Full martian year of simulated ozone with heterogeneous chemistry (left) and homogeneous chemistry (right) at latitude 0° with 48 timesteps per sol. Time is given in solar longitude, L_S .

1-Dimensional model



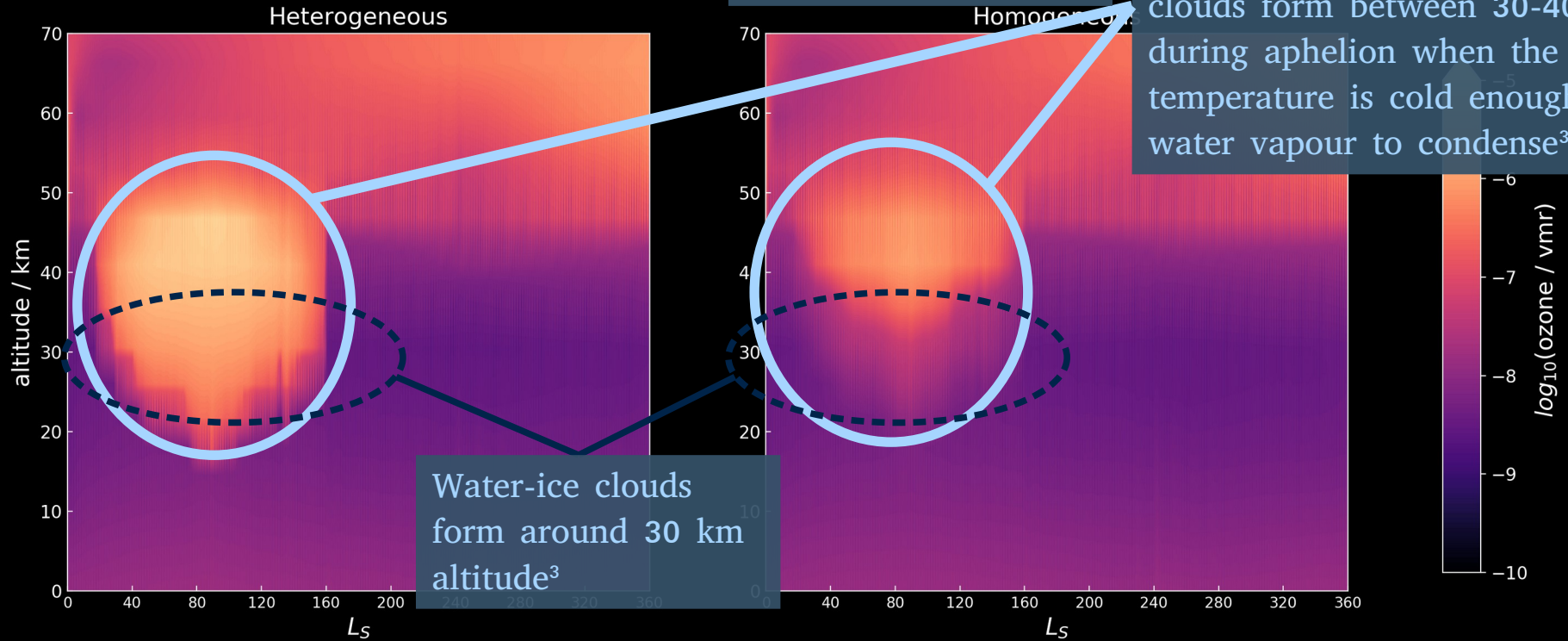
Water-ice clouds also form at high latitudes during the winter^{1,2}



The ozone abundance is a result of a feature called the Aphelion Cloud Belt; water-ice clouds form between 30-40 km during aphelion when the temperature is cold enough for water vapour to condense^{3,4}

¹Benson et al. (2010); ²Benson et al. (2011); ³Mateshvili et al. (2007); ⁴Wolff et al. (2019)

1-Dimensional models



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1-Dimensional model

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The current heterogeneous scheme over-predicts ozone abundance (Clancy et al. 2016)

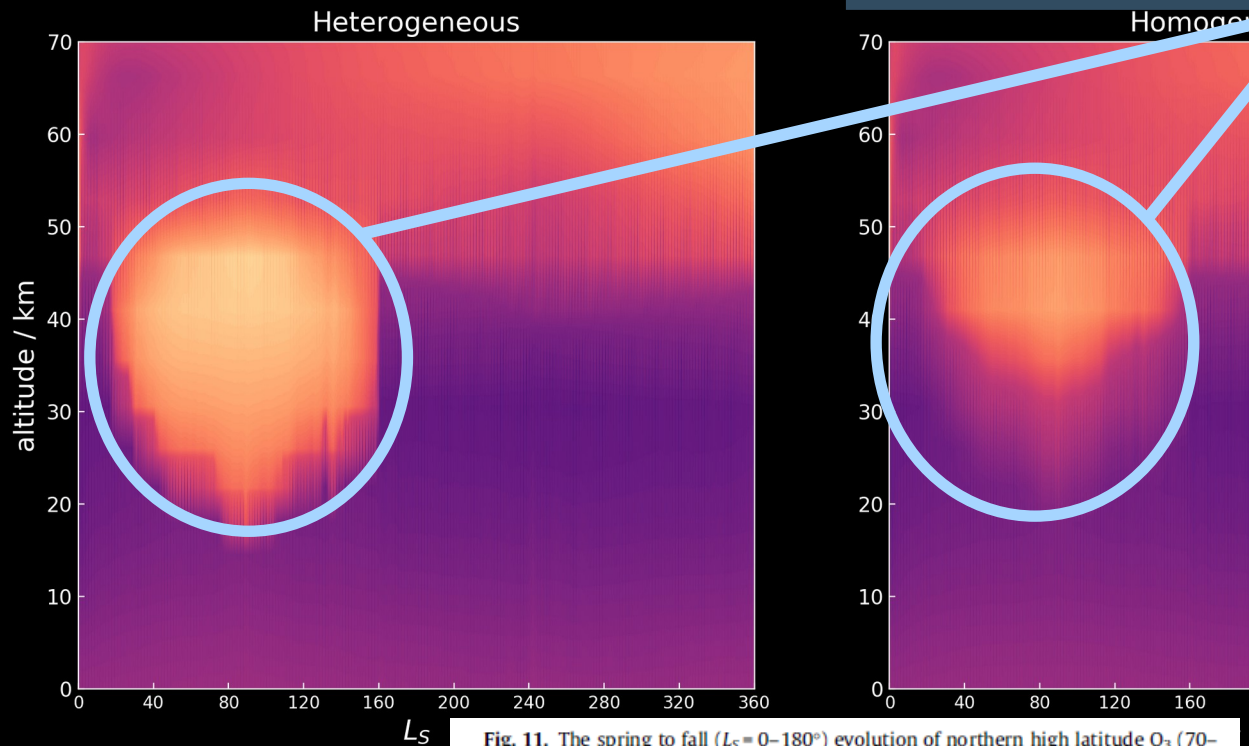
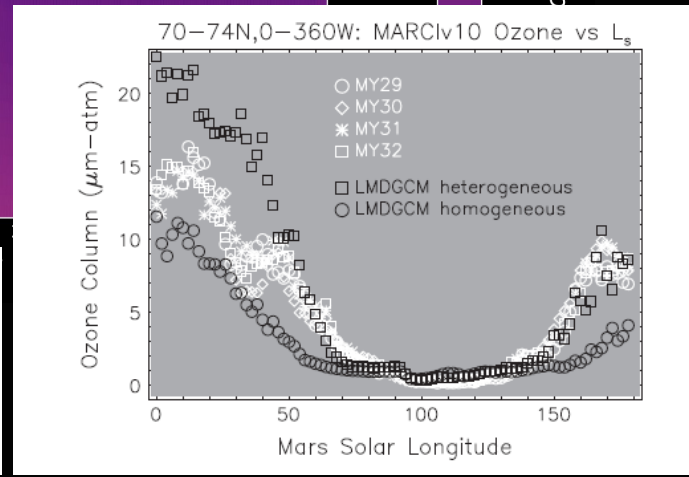


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¹Benson et al. (2010); ²Benson et al. (2011); ³Ma

Next steps

- Test 1-D model at high latitudes where clouds are expected to form
- Use observed vertical profiles of water vapour to simulate a more accurate water cycle
- Develop heterogeneous reactions between hydroxyl radicals and water-ice clouds
- Validate/compare results with ozone and water-ice observations from ExoMars Trace Gas Orbiter

Summary

- ♦ Ozone is photosensitive and anti-correlated with water vapour
- ♦ Current global climate models either over- or under- predict ozone abundance depending if the model is run with heterogeneous chemistry
- ♦ This project uses a 1-D model to test and develop the heterogeneous chemistry, using ozone abundance to highlight these effects